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ABSTRACT

Data from the pilot use of a mathematical applications in science course for secondary-school pupils are presented. The course was offered in a variety of ways. Among these were: 1) as a one-semester elective course to sophomores who were planning to study chemistry; 2) as part of a physical science course for low achievers; 3) as part of a chemistry course; 4) as part of a physics course; and 5) as part of a special biology and algebra sequence in an inner city school. The achievement of all students are presented, as measured on special pre- and post-tests. Among the conclusions, the program is seen as helpful, capable of teaching new skills, well developed, coherent, and well received by students and teachers. The biggest problems were: 1) how and where to place the program in traditional educational settings; 2) the appropriate grade level; and 3) how to implement it in traditional time settings. It was found that the program involves a unit of time that does not mesh well with quarters, semesters, or year-long courses. (MP)

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Final Report

SCI MATH

FINAL REPORT

PHASE TWO, SECONDARY COURSE IN
APPLICATION OF MATHEMATICS TO SCIENCE

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Note

Chapters One through Six of the following "Report on Phase Two, Sci-Math Project" will be sent to the administration of each of the schools who participated in Phase Two. To preserve anonymity where possible, code names have been used for each of the schools and teachers mentioned in this report. The identification of the code for the schools, only, appears in Appendix B. None of the Appendices is being mailed to the schools. School Administrators who request it will be given any Tables from Appendix B which refer to their own schools; such tables will be given with the code names instead of the school names.

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PREFACE

We have said it in other places, but we would like to repeat it here. Thanks and deep appreciation are owed to the schools and staff who voluntarily gave their time, effort, and skills to participate in this project. Innovation is expensive in many ways, not only in the financial costs generously assumed by the National Science Foundation but in the sheer dedication needed to get it going and to maintain it. Administrators, teachers, parents, and students all must be willing to take the risks that accompany any venture out into the unknown. It is to the credit of our schools and citizenry that projects like this are undertaken in the cause of furthering good education.

There cannot be enough praise said for the teachers who actually taught the course, who did all the extra work needed to teach a new curriculum, who made helpful suggestions to us, who worried over their students and over how to present the material to them, who were willing to step out of the safe school daily routine to try something different. We are fortunate to have been able to work with them.

MPG
February, 1982

PHASE TWO, SECONDARY COURSE IN APPLICATION OF MATHEMATICS TO SCIENCE: THE SCI-MATH PROJECT

SUMMARY OF PLANS

This report is concerned with Phase Two of a project funded to develop a curriculum on proportional calculations

Purpose The purpose of Phase Two of this project was to revise the curriculum which had been developed and field-tested in Phase One of this project, and to field-test the revised curriculum in a variety of school environments. The curriculum is intended to reach the skills and understandings needed by secondary students to apply the mathematics of proportions to the introductory secondary sciences. A discussion on "Rationale" appears in the report on Phase One of this project.

Objectives The objectives of this project were to:

(1) Revise the curriculum developed and field-tested in Phase One so as to be used for a semester (half-year) course in mathematics which teaches understanding of real world variables and their relationships through rates, direct proportions expressed by rate equations, dimensional analysis, ratios, the connections between ratios and rates, percentages, inverse proportions, algebraic equations to express proportional relationships, and graphing various types of proportions in association with their algebraic equations.

(2) Construct a teacher's guide for the curriculum.

(3) Arrange for the offering of the curriculum in a variety of secondary schools in the State of Connecticut, both as an elective semester course, and as part of a regular chemistry and regular physics course.

(4) Field-test the curriculum in these schools.

(5) Evaluate the curriculum both formatively and summatively using an appropriate statistical design.

(6) Disseminate information about the project to educators.

(7) Seek commercial publication of the project materials.

CHAPTER ONE

PROCEDURE

I. PARTICIPATING SCHOOLS AND TEACHERS

A list of the participating schools in this project may be found in Table I. To help initiate Phase Two of the project, a newsletter about the first phase of the project was sent out to all secondary schools in Connecticut. The newsletter invited interested teachers to contact the Project Director. After preliminary talks, a meeting was held with the teachersand administrators in each of the schools that showed interest. To incorporate a new curriculum into a school offering, approval was always required by the Board of Education and/or the Superintendent of Schools through a multi-step process. After this lengthy process was successfully completed, the Project Director met with the reponsible teachers and administrators, presented the materials, and discussed the responsibilities of the project and of the school. Arrangements were made for recruitment and for experimental and control groups. The importance and nature of the testing and records needed were stressed.

The project supplied textbooks, a teacher's guide, and laboratory materials to the participating schools, and the Project Director made regular visits to each school during the course of instruction. A special meeting was held with all the participating teachers in the semester elective course as a group prior to instruction to discuss the project, and a newsletter was mailed out to participating teachers at irregular intervals to help in the exchange of ideas and suggestions. Copies of the newsletters mailed to participating teachers may be found in Appendix A.

At Iota (see Table 1) where sci-math was integrated into the regular chemistry course, meetings were held at two-week intervals with the chemistry and physics teachers to coordinate the effort during the academic year of instruction.

Many of the teachers who gave the instruction in sci-math during the project were the same ones who had made the initial contact for us with the school. Three of the teachers, at Theta, Gamma, and Zeta, elected to teach the course as extra load. Table 1 lists the relevant experience of the teachers in the project.

Following the completion of the elective semester of sci-math, a meeting was again held with the teachers to elicit their recommendations for the future. This is summarized in Chapter Five on formative evaluation.

II. CURRICULUM REVISION

During the Fall semester of 1979, the Project Director, Madeline P. Goodstein, Professor of Chemistry at Central Connecticut State College, revised the instructional materials for mathematics for introductory science (Sci-Math) in accordance with the critique in the Report on Phase One of this project. The revised materials were reviewed by the Advisory committee (for names of the members of the Committee, see the preface to

TABLE 1

SUMMARY OF DESCRIPTIONS OF PARTICIPATING SCHOOLS

CODE NAME OF HIGH SCHOOL	SCI-MATH	SCI-MATH TEACHER	TYPE OF SCHOOL	SCI-MATH CONTROL GROUP	SIZE OF CONTROL GROUP	SIZE OF EXPER. GROUP	FOLLOW-UP IN CHEMISTRY	TIME GIVEN TO SCI-MATH (MIN.)
Alpha	TAUGHT ONE SEMESTER AS AN ELECTIVE COURSE PRIOR TO TAKING CHEMISTRY	CHEM.*	SMALL CITY; LOWER ECONOMIC LEVEL	PSEUDO	19	10	NO	NO RECORD
Beta		MATH	INNER CITY	REGULAR	7	10	NO	2730
Gamma			SUBURAN-MIDDLE ECONOMIC LEVEL					
TEACHER A		CHEM-MATH*		REGULAR	17	15	YES	3850
TEACHER B		MATH-CHEM.				19	YES	2825
Delta		MATH	SUBURAN-RURAL	REGULAR	16	22	YES	3013
Epsilon		CHEM-MATH.	CITY: PAROCHIAL ALL MALE	REGULAR	33	30	YES	1840
Zeta		CHEM.*	SUBURAN-RURAL	PSEUDO	19	17	YES	2240
Eta	PART OF ONE-YEAR TERMINAL PHYSICAL SCIENCE FOR 11-12 GRADE LOW ACHIEVER	CHEM.*	SUBURAN	REGULAR	14	14	NO	
Theta	PART OF ONE-YEAR COURSES EACH IN BIOLOGY & MATHEMATICS SCHEDULED BACK-TO BACK. PRE-CHEMISTRY STUDENTS	MATH.*	INNER CITY	NONE		15	NO	

(continued)

TABLE 1 (continued)

SUMMARY OF DESCRIPTIONS OF PARTICIPATING SCHOOLS

CODE NAME OF HIGH SCHOOL	SCI-MATH	SCI-MATH TEACHER	TYPE OF SCHOOL	SCI-MATH			FOLLOW-UP IN CHEMISTRY	TIME GIVEN TO SCI-MATH (MIN.)
				CONTROL GROUP	SIZE OF CONTROL GROUP	SIZE OF EXPER. GROUP		
Iota								
Chem; Teacher A (2 sections)	PART OF ONE YEAR CHEMISTRY COURSE	CHEM.	SUBURAN-MIDDLE ECONOMIC LEVEL	REGULAR	16	38	YES	± 120[illegible]
Chem; Teacher B		CHEM.	MIDDLE ECONOMIC LEVEL	REGULAR	16	20	YES	± 1200
Physics	PART OF ONE YEAR PHYSICS COURSE	PHYSICS		REGULAR	18	20	FOLLOWED IN PHYSICS	
TOTAL: 9 SCHOOLS 12 TEACHERS 13 SECTIONS	7 SECTIONS ELECTIVE SCI-MATH, 6 SECTIONS-OTHER	5 CHEM. TEACHERS, 3 MATH. TEACHERS, 3 CHEM-MATH TEACHERS, 1 PHYSICS TEACHER		9 CONTROL 2 PSEUDO 1 NONE	175	236	7 SECTIONS FOLLOWED-UP IN CHEM., ONE IN PHYSICS	

* The asterisk indicates that this teacher initiated contact with the project. Where the teacher was certified in both mathematics and chemistry, the first discipline listed is the one the teacher taught at the time of the project.

"Sci-Math Part I" in this packet), and further revisions were made based upon their suggestions. The new materials were printed in three bound paperback volumes and teachers were given thirty copies of each for each section of students taught. The Project Director wrote a teachers' guide with suggestions for instruction and fully-worked out solutions to all problems. Each participating teacher received a copy of the guide.

Also, during the summer of 1980, the Project Director worked out a schedule for the incorporation of selected portions of the sci-math materials into the regular chemistry course to be taught at Iota in 1980-81. A detailed teacher's guide was prepared, which included instruction on how to integrate the sci-math materials into the regular chemistry instruction.

III. COURSE OFFERINGS

As shown in Table One, the sci-math materials were offered in a variety of ways. There were seven sections in six schools where it was given as a one-semester elective course available to sophmores who were planning to study chemistry. In another school, it was given as a part of a physical science course for low achievers and, in still another school, it was offered to students taking biology and algebra in a special sequence. Finally, it was also offered as part of a chemistry course and as part of a physics course. Details follow next.

A. Elective Course

At six schools, arrangements were made to list an elective course in sci-math in the regular catalogue of courses. The course was to be given for one semester in the second half of the school year, and was described as a preparation in mathematics needed to take the course in chemistry for college-bound students.

At every school except Epsilon, it was necessary to recruit in order to obtain sufficient registration. In some schools, the chemistry teacher went into the science classes to recruit. In some, the current science teacher did the recruiting. In others, the mathematics teachers helped with recruiting. At Epsilon, practically every ninth grader volunteered to take the course in tenth grade and so no recruitment was necessary.
As an inducement to recruitment, no homework was assigned at any of the schools

1. Real Control Groups.

In those schools where there was sufficient registration for the elective sci-math course, half of the students were randomly allowed into the course while the others were told that there was no more room. The latter became the control group. At Gamma, enough students volunteered to permit two experimental groups and one control group; the administration decided to assign teachers to the two experimental groups. At Delta, and at Epsilon where registration was also very high, only one experimental section was randomly set up, and the control group was randomly selected from the remainder.

2. Pseudo-Control Groups

In two schools, Beta and Zeta, where the population for the chemistry course was relatively low, it was anticipated that there might be insufficient enrollment to fill both the experimental and control groups. In those schools, the students taking biology one year earlier than the others in our study (sci-math was usually studied in the same year that the student took biology) who stated that they were willing to take an elective sci-math semester, were given the complete battery of tests at that time even though the course was "withdrawn." They were designated the pseudo-control group and were used as the control group in our field-test in those two schools, Zeta and Alpha. Their data was compared to the experimental group who were given the tests and the sci-math elective course the following year.

B. <u>Part of a Physical Science Course</u>

At Eta, the sci-math materials were incorporated into a terminal one-year physical science course regularly offered to sophmore and juniors who are low achievers. Of four sections taking this course, one of the two largest was designated as an experimental group and the other as a control. The sci-math materials were used for most of the second semester of this course.

C. <u>Part of a Chemistry Course</u>

At Iota, two chemistry teachers incorporated selected parts of the sci-math text and experiments into their regular chemistry course offered to students who were planning to go to college. One teacher taught the materials in two experimental sections with another of his chemistry sections as a control group; the other teacher taught it to one experimental section with another section as a control group.

D. <u>Part of a Physics Course</u>

The sci-math textbook, without experiments, was incorporated as a whole into the regular physics course for one section at Iota. A second section was used as the control group. The students did selected problems from the entire text as required home work with discussion and quizzes in class. Very little class time was used. However, from five to seven students who had trouble with the materials received special help from the teacher.

E. <u>Part of a Special Sequence in an Inner-City School</u>

At Theta, an elective semester of sci-math was scheduled for the last period of the day. Although the class had sufficient registration initially, attendance by the students, all black or Hispanic, gradually fell off as the semester progressed largely because the students left to go to work. As a result, not enough data was collected for analysis of achievement. The teacher, who was Head of the Mathematics Department, requested that the materials be used the following year with a different sample; no control group would be available. Because of our interest in this disadvantaged group of students, we agreed. By pre-arrangement, the course was taught the following year by the mathematics teacher to a section of students, all black or Hispanic, who were taking biology and algebra in periods that were back-to-back. One period per week was released in algebra and one period per week in biology for the academic year to be used for instruction in sci-math. Since our project terminated at the end of the year, we could follow the achievement of the students in sci-math but not in the chemistry course that they were expected to take subsequently. Hence, this section constituted a special study in our project.

IV. SUMMATIVE EVALUATION

The design for the summative evaluation of the field-test of the materials produced by this project and the statistical evaluation of the data were carried out by D. William W. Boelke of the Department of Applied Mathematics at Central Connecticut State College.

With the exception of the section at Theta where there was no control group, this study involved a pre-and post-test with experimental and control groups made equivalent through randomization. See the Report On Phase One for a discussion of the statistics used. The complete analysis carried out by Dr. Boelke appears in Appendix B along with a discussion of the experimental design. Chapters Two to Four of this Report give a condensation of the analysis with inferences and conclusions. In Phase Two, the means of several samples were compared by a one-way analysis of variance with an F-test. When the F-test showed that the means were not the same, all possible paired comparisons of the means using T-Tests were done; the significance level was corrected for degrees of freedom using the Data-text computer program.

The pre-test used was a project-devised test based on a revision of the tests used during Phase One of the Project. This test covered the topics taught in sci-math which did not involve special definitions and terms taught during the semester (which were unknown to the control group). A matched post-test was given at the end of the study of sci-math. The experimental groups also took a post-test on sci-math questions that included only items with special terms and definitions; a report on this test can be found in Appendix B.

To evaluate chemistry achievement, a project-devised test was given; see Chapter Four for a discussion of this test. Also used was the American Chemistry Society-National Science Teachers Association standardized chemistry test called the ACS-NSTA Chemistry Test.

The tests used appear in Appendix C.

V. FORMATIVE EVALUATION

An outside agency, Karen Cohen Associates, Inc., was hired to conduct a formative evaluation of Phase Two of the project. A complete report by Dr. Cohen and associates may be found in Chapter Five of this report.

In addition, attitude tests were given to some of the experimental and control sections as part of Dr. Boelke's analysis. Finally, the teachers who instructed the semester sci-math sections met for one day after completion of the course to critique it. This critique is summarized in Chapter Five.

The teachers were also asked to keep logs on the topics and experiments. These logs contained time spans, corrections for errors in typing, and comments and will be used for revision of the materials for publication.

VI. DISSEMINATION AND PUBLICATION

A total of thirteen papers, two workshops, and three poster sessions were presented to science education and mathematics education local, regional, and national organizations. Two papers have been submitted for publication, three articles were published, and descriptive paragraphs appeared in many state science and mathematics education publications. Five newsletters were mailed to 300-600 interested teachers upon request. The newsletters appear in Appendix D.

Publishers for the completed work were solicited and arrangements are now in process for publication.

Details of dissemination and publication appear in Chapter Six.

CHAPTER TWO

ACHIEVEMENT IN SCI-MATH: TOTAL SCORES

I. OVERVIEW

This chapter evaluates the achievement of the students as measured by total scores on the sci-math curriculum pre- and post-tests.

Thirteen class sections in ten schools were taught sci-math either as a one-semester (one term or academic half-year) elective course or as part of a regular one-year science course. The students were pre-tested before beginning the course and then post-tested at the end with a matched, scrambled test. The results are given in this chapter for the total mean scores in each section for eleven of the twelve test items. The twelth item is excluded because only the physics class at North Haven High School covered that topic during the instructional period. Each question poses a different type of problem involving direct or inverse proportions. See Appendix C for the tests. A more detailed description of the analysis than is given in Chapters Two to Four may be found in Dr. Boelke's report in Appendix B.

All scores in this and subsequent chapters for sci-math test items were counted as correct if the procedure given (that is, the arrangement of quantities for calculation) is correct. No deductions were made for arithmetical errors.

The results of the analysis are given in this chapter for each of the following groups in turn:

(1) Semester elective sci-math course: seven sections consisted of the students who elected to study one semester of the special offering of the sci-math curriculum. The seven sections were in six schools with six control groups.

(2) Required course taken by low achievers: two schools gave the curriculum as part of an already existing course. In both cases, the students were low achievers in mathematics as shown by the pre-test scores. At one school, there was one experimental and one control section; the other school had one experimental section and no control group.

(3) Part of regular chemistry of physics course: one school incorporated selected parts of the sci-math curriculum into its regular chemistry course for students intending to go to college. At the same school, the entire curriculum, without experiments, was assigned as part of the regular physics course. There were three experimental sections and two control sections in chemistry, and one experimental and one control section in physics.

II. COMPARISONS OF BACKGROUNDS OF SAMPLE

For the purposes of analysis, the seven experimental sections taking the elective semester of sci-math were pooled; the six control sections were divided into the two pseudo-control sections and the four regular sections (see Section IIIA for explanation). Table II compares the experi-

TABLE II

COMPARISON OF BACKGROUNDS, EXPERIMENTAL AND CONTROL GROUPS

Section		Highest Mathematics STUDIED[1]				Gender				Grade Level			
		Control		Exper.		Control		Exper.		Control		Exper.	
		N	Score	N	Score	N	Score	N	Score	N		N	
Elective Sci-Math	Real Control	71	5.15			73	1.25[2]			66	10.000		
	Pseudo-Control	37	5.00			38	1.55			38	10.05		
	Experimental			117	5.00	122	1.42			122	10.098		
Low Achievers		12	4.50	12	4.42	12	1.58	12	1.38	14	10.14	14	[illegible]
Chem. A		13	5.69	32	5.53	21	1.29	38	1.53[3]	21	11.05	40	10.[illegible]
Chem. B		14	5.56	18	5.79	17	1.71	20	1.60	17	11.06	20	[illegible]
Physics		17	7.12	18	7.00	20	1.50	20	1.50	21	11.95	20	[illegible]

[1] For an explanation of the scoring system. see Table 8, Appendix B.

[2] There is a significant difference at the 5% level by a T-test in gender between five sections of the real control group, and the 7 sections of the experimental group who took an elective semester of sci-math. The control group had more females.

[3] The gender difference is at the 7% level of significance. The experimental group had more males.

mental and control sections with respect to highest mathematics studied, gender, and grade level. The sections were alike in highest mathematics studied and in grade level. There was a significant difference in gender at the 5% level, by a T-test, between the pooled seven sections of the experimental group and the pooled four sections of the control group; the control group had more females. There was no gender difference between the experimental and pseudo control groups.

There was no significant difference in highest mathematics studied, gender, or grade level between the experimental and control groups of low achievers at Eta. No comparison was possible for the other school where the students were low achievers (Theta) since it had no control group.

The chemistry and physics courses in our field-test were given at Iota. One chemistry teacher taught two experimental sections and one control section; another chemistry teacher taught one control and one experimental section. We have labeled these as A and B respectively. The physics teacher taught one experimental section and its control section. There were no significant differences in highest mathematics studied or grade level between any of these experimental and respective control sections. Except for Chemistry A, there was no difference in gender. The Chemistry A experimental and control sections differed at the 7% level of significance; there were more males in the experimental group.

Thus, except for gender, there were no significant differences in highest mathematics studied and grade level between any of the experimental and control sections.

Table II also shows that the highest mathematics studied (see Table 8 of Appendix B for a detailed explanation of the scoring) was geometry for the elective sci-math semester group, algebra I for Eta, algebra II (half-year) for the chemistry sections, and an advanced pre-calculus course for the physics section.

The pooled semester elective sections and the Eta sections enrolled tenth graders, the chemistry sections enrolled eleventh graders, and the physics students were seniors.

III. COMPARISONS OF PRE- TO POST-TEST SCORES

On these tests, full credit was given even if there was an arithmetical error provided that the procedure was clearly correct.

A. Semester Elective Sci-Math Course

Table III gives the separate data for the seven experimental sections who took the one-semester elective course and their control groups. For each of these sections, there was no significant difference between the pre-test score of the experimental group and its control group. However, there was a significant difference in each case for the post-test scores of the experimental and corresponding control group. Also, the gain between pre-test and post-test scores for each experimental group was significantly higher than for the corresponding control group.

TABLE III

ELECTIVE SEMESTER: COMPARISON BY T-TEST OF MEAN SCORE, TOTALS OF PRE- AND POST-TESTS, AND GAIN, FOR EXPERIMENTAL AND CONTROL GROUPS 1,2

SECTION	TYPE OF CONTROL	N CONTROL	N EXP.	Pre-Test CONTROL	Pre-Test EXP.	Post-Test CONTROL	Post-Test EXP.	Gain: Pre-T[illegible] to Post-Test CONTROL	Gain: Pre-T[illegible] to Post-Test EX[illegible]
1. Alpha	Pseudo	19	10	2.737	2.100	2.737	4.100*	0.000	2.0[illegible]
2. Zeta	Pseudo	19	17	2.632	2.176	3.158	5.118*	0.526	2.941***
3. Delta	Real	16	22	2.687	2.182	3.187	5.909**	0.500	3.7[illegible]
4. Beta	Real	7	10	1.857	2.200	1.000	6.800***	-0.857	4.60[illegible]
5. Gamma Teacher B	Real	17	19	2.882	2.421	3.824	5.895**	0.941	3.47[illegible]
6. Gamma Teacher A	Real		15		2.600		7.400***		4.80[illegible]
7. Epsilon	Real	33	30	2.424	2.967	1.576	3.800***	-0.848	0.833***
POOLED DATA, REAL CONTROL		4 sect-ions 73	7 sect-ions 123	2.534	2.455	2.397	5.390***	-0.137	2.[illegible] *
POOLED DATA PSEUDO CONTROL		2 sect-ions 38	7 sect-ions 123	2.684	2.455	2.947	5.390***	0.263	2.935***

[1]Sections 1-7 are arranged in order of experimental pre-test scores.

[2]For each pair of results, in all tables in this report the experimental group is compared to the control group by the modified T-test. One asterisk over the experimental results shows that they differ at the 5% level (85% level of confidence), two asterisks at the 1% level, (99% level of cofidence), and three asterisks at less than 0.1% (99.9% level of confidence).

The scores of the tests were pooled for the seven experimental sections, for the four control sections, and for the two pseudo control sections. The pooling is justified because there is no significant difference between pre-test scores for the three groups by the T-test (in this study, the T-test always follows an F-test). The results for the pseudo-control group were not pooled with the real control groups in part because there was a difference in the wording of the eleventh question on the pre-test. The pseudo groups received their tests one year earlier than the real control groups (See Chapter One, Section IVA). When it was observed by the Project Director that there was difficulty in judging the correctness of some of the answers to the eleventh question, the question was altered on the tests of the real control group to remove the ambiguity. However, it must be mentioned that neither of the experimental groups matched to the two pseudo control sections was taught the topic of Question 11 during the sci-math course, although some of the experimental sections pooled with the regular control groups did cover it. Another reason for not pooling the data of the pseudo control group with the regular control group is because the one-year time difference may have caused the environment of the pseudo control groups to differ more from the experimental group than did the environments of the real control group. There was no way to reasonably measure this effect; the study was nonetheless judged worthy of the effort.

Table III shows the means for the pooled experimental group and compares them to the means of the pooled real control and the pooled pseudo control sections. In all tables in this report, asterisks over a modified T-test or other test result show that group to be significantly superior. One asterisk shows that they differ at the 5% level of significance (95% level of confidence), two asterisks at the 1% level of significance (99% level of confidence), and three asterisks at below the 0.1% level of significance (99.9% level of confidence). (See Appendix B for data that show there were no significant differences in pre-test mean scores between the pooled real control and pooled pseudo control groups.) In both cases, the experimental group significantly outperformed each control group at the 0.1% level of significance even though there were no significant differences in pre-test scores. Also, the experimental group gained significantly for pre- to post-test scores compared to either control group.

Hence, the evidence supports the hypothesis that a one-semester elective course for pre-chemistry secondary students in sci-math significantly improves the achievement of students in the sci-math curriculum.

B. Required Course, Low Pre-Test Achievers

At Eta, the sci-math curriculum was taught as the second semester of a required physical science course of low achievers who were high school sophomores. Another section of the same course served as the control group.

At Theta, sci-math was taught for two periods per week for one year to a class of pre-chemistry sophomores taking a one-year biology course and a one-year mathematics course specially scheduled back-to-back. The algebra II and biology teachers each gave one period a week for one year for this purpose; the algebra teacher instructed the students in the sci-math curriculum. Theta is an inner-city school with a predominatly black-Hispanic student body. Because of the unique scheduling, there was no comparable control group available. The time period actually used for instruction was equivalent to about half of a semester of regular five-period weeks.

These two schools were sharply distinguished from the other schools in our study by the low scores on the pre-tests. Hence, even though the experimental treatment and the statistical treatments for these schools are not comparable, we will consider their data side-by-side.

Eta completed the first five chapters of the sci-math materials (a little more than half of the curriculum). Theta completed the first two chapters and parts of the next two.

Table IV shows that both Eta and Theta made significant gains. The Theta group, which had the lowest pre-test scores in our study, tripled the score on the post-test. The Eta section, which had scored next-to-lowest on the pre-test, almost quadrupled the score. The Eta post-test scores surpassed the post-test scores of the control groups of all seven schools which offered the elective course; that is, the Eta students ended the semester of study at the level of the control groups, for proportional problem solving, who were planning to go on to the study of chemistry.

Inclusions of both the Theta and Eta sections were not part of the original plan of this project. Both schools replaced other schools which had to drop out of the project. It is fortunate that these replacements occurred because they made possible the inference that the first half of the sci-math materials can be successfully learned by low achievers. This is especially interesting in view of the fact that sci-math teaches every-day consumer and applied problems in direct proportions without algebra in the first half of the book. While the materials were originally aimed at pre-chemistry students, we see that the potential impact is much broader.

C. Sci-Math Integrated into a Regular Chemistry Course

The Iota Science Department undertook to include selected parts of sci-math in its chemistry course. The chemistry teachers requested that the amount of time used for the sci-math materials be kept to a minimum, and so only selected parts of the text were integrated into the course. One of the two chemistry teachers taught two experimental sections and one control section (Chemistry A), while the other taught one experimental and one control section (Chemistry B). The students did many less problems than in the other schools in our study.

Although the chemistry students were juniors (see Table II) who had taken an average of one more semester of mathematics than had the sophomores in the elective sci-math semester course, they did not test higher on the pre-test then the sophomores who elected sci-math. Pre-test scores showed that the combined two chemistry sections of Chemistry A pre-tested significantly better than did their control group. When the pre-test scores of the three sections of Chemistry A and Chemistry B were pooled, the scores of the experimental group did not differ significantly from those of the control group; hence we will consider the pooled results for the three chemistry sections.

TABLE IV

REQUIRED COURSE: COMPARISON BY T-TEST OF MEAN SCORE TOTALS OF PRE- AND POST-TESTS, AND GAIN

	N		Pre-Test		Post-Test		Gain	
	Control	Exp.	Control	Exp.	Control	Exp.	Control	Exp.
THETA		21		0.524		1.579[1]*		
ETA	14	14	1.000	1.000	0.643	3.857***	-0.357	2.857***
CHEMISTRY A, IOTA	16	2 sections 38	2.875	2.237	2.765	3.455	0.071	6% level 1.182
CHEMISTRY B, IOTA	16	20	1.813	3.450***	2.286	4.278***	0.692	1.000
COMBINED CHEMISTRY	32	58	2.344	2.655	2.548	3.745**	0.370	6% level 1.118
PHYSICS IOTA	18	20	5.111**	3.400	6.286*	4.529	1.083	0.941

1 The difference between the pre- and post-test scores for Iota, N=15, on a non-parametric sign test was significant at the 5% level.

Table IV shows that the post-test scores of the experimental group were greater than those of the control at the 1% level of significance, and that the gain for the experimental group was greater than that of the control group at the 6% level of significance. This is encouraging in view of two facts, first that only about one-third of the sci-math materials was taught in the course with less time and with much less drill than for the semester elective course and, second, that the control group was taught dimensional analysis, which is part of sci-math, as part of the regular chemistry course. Despite such instruction, the control group made almost no gain from pre- to post-test, unlike the experimental group.

D. Sci-Math as Part of a Physics Course

The sample population in the physics course at Iota consisted of seniors, evenly distributed by gender, who had all completed algebra II and geometry and were taking or had taken one or more additional courses in mathematics. One physics section was randomly picked as the experimental group with the other as a control. The control group was significantly superior to the experimental group in sci-math at the beginning of the year of physics and they maintained the same lead at the end of the year. The small gain by both groups during the year was insufficient to elevate the experimental group by the end of the year to the level which the control group had initially. See Table IV.

The physics teacher regularly assigned selected problems from the text to the experimental group and gave quizzes on these in class. He met separately with the three to six students in the group who had trouble with the problems. No experiments from the sci-math text were used. The entire curriculum was completed in this way.

Because the gains made by both groups were small and about the same, it seems likely that students taking physics are a self-selected group who have already learned or will learn via physics most of what they can learn about proportional problem-solving.

IV. CORRELATION OF GAIN WITH OTHER VARIABLES

A. Length of Instructional Time Correlated with Course Achievement

Since data had been collected for the length of classroom time given to sci-math for six of the seven sections that studied it for the one-semester elective course (see Chapter One, Table 1), it was possible to statistically examine the correlation between class time and gain in achievement.

Null hypothesis: There is no correlation between the amount of class time and gain in achievement of the experimental group compared to that of the control group for the elective sci-math sections.

Table V (same as Table 21, Appendix B) gives the results of a Spearman Rank Correlation test of the gains for six elective semester sections. The times given on the chart omit the periods used for pre- and post-testing but include quiz and chapter test time.

TABLE V

SPEARMAN RANK CORRELATION COEFFICIENT
BETWEEN TIME SPENT IN TEACHING AND TOTAL GAIN

	Total Time in Minutes	Rank of Time	Rank of Gain	d diff	d^2
Epilson	1840	1	1	0	0
Zeta	2240	2	2	0	0
Beta	2730	3	5	-2	4
Gamma Teacher B	2825	4	3	1	1
Delta	3013	5	4	1	1
Gamma Teacher A	3850	6	6	0	0

N = 6

$r_s = 1 - \frac{6\Sigma d^2}{N^3-N} = 0.829$*

$\Sigma d^2 = 6$

Critical Value at 5% for N=6 is 0.829

Table V shows that a significant correlation exists between class time and achievement; the null hypothesis is rejected. If the instructional time for the pooled data from the chemistry sections at Iota is included in the calculations, $r_s = 0.893$, improving the significance.

While it might seem that class time should always be correlated with achievement, this does not necessarily follow at all. For example, the method of ratio and proportions for solving proportions problems had already been extensively studied in prior coursework at most of the participating schools, yet pre-test scores were relatively low. Also, many teachers will attest to experience with students who earnestly re-take a course after receiving a failing grade in it only to fail again. In such cases, a new approach is needed. Apparently, sci-math supplies such a new approach.

B. Gain Correlated with Total Quantity of Mathematics Studied

Another variable to consider with respect to gain in achievement is whether the gain was related to the level of mathematics already studied by the students. The mathematics courses which the students had taken were categorized into 8 levels, and Pearson's product moment correlation coefficient was calculated for the gain in total score. The correlation coefficient was close to zero and not significant. (See Table 9 in Appendix B.) Two opposing factors may have operated to cause this result. First, it is likely that better achievers, who take higher courses in mathematics, were better learners and so could learn more from the course. Opposing this is the possibility that their higher pre-test scores set a ceiling on the amount that they could gain.

A correlation analysis for each individual test question showed coefficients from +0.07 to -0.08 for ten of the eleven questions, none at the 5% level of significance. Only the percentage question gave a significant correlation, -0.151 at the 5% level. This suggests that lower achievers benefited more from the instruction in percentage than the higher achievers who already understood it.

C. Order of Means of Pre- and Post-Tests

The order of the means of the classes on the pre- and post-tests were compared to each other by a Spearman rank-order correlation coefficient. The correlation was not significant at the 5% level; see Table 5 in Appendix B. It has already been shown that time spent in teaching was correlated with the means; this may explain part of the lack of correlation.

V. DELAYED POST-TEST

After an interval of one summer, the students in the sample who were beginning their study of chemistry at Gamma were again administered the post-test. The sample was now much smaller (see Chapter Four, III A); the results are shown in Table VI. The scores of the experimental and control groups now differ at above the 5% level of significance; (significance level is 6%).

To judge the effect of the course on re-learning, the post-test was administered at Epsilon immediately after dimensional analysis was briefly taught in chemistry. The data appears in Table VI. Here, a significant difference appears in favor of the experimental group; the sci-math course makes a difference in achievement on relearning.

Any comparison of these post-post test results must be regarded as highly tentative since they deal with two different schools and since one school had a small enrollment for this part of the study.

VI. Summary

The treatment sections (studied sci-math) were significantly superior to the control sections in a pre-post test and gain in pre-post test design comparing experimental and control groups for (1) seven pooled experimental sections who elected a sophomore semester of sci-math, for (2) a section of sophomore low achievers who studied the first half of sci-math for a half-year as part of a required one-year physical science course and for (3) three pooled chemistry sections who took selected parts of sci-math as a part of the usual one-year chemistry course. The F-test followed by an T-test was used for the analysis. There was a total of 352 students involved in this part of the study.

A treatment section of racially disadvantaged students with very low pre-test scores was pre- and post-tested. The gain was significant on a non-parametric test.

A treatment section of physics students made non-significant gains compared to a control group.

It is concluded that significant gains in proporational calculation skills can be attained from the study of sci-math by non-honors students in tenth grade, including low achievers and the racially disadvantaged.

The amount of class time in the treatment was significantly correlated with gain in achievement. There was no significant correlation between total mathematics previously studied and gain in proportional calculation skills for the treatment group. The order of means on the pre-test for the treatment group was not significantly correlated with the order of means on the post-test.

On a delayed post-test after a summer's interval, the difference in pre-post test scores at one school dropped to below significance (6%). At another school, after re-teaching dimensional analysis as part of the chemistry course, there was a significant difference in gain between the experimental and control groups. These results suggest that the gain is long-term.

TABLE VI

DELAYED POST-TEST, T-TEST COMPARISON, EXPERIMENTAL AND CONTROL GROUPS

Gamma	N	Total Raw Score	Significance	Questions on Test with Significant Difference
Exp.	10	6.200	0.061	6
Control	9	4.556		
Epsilon				
Exp.	25	4.560	0.021	1, 2
Control	25	2.920		

CHAPTER THREE

ACHIEVEMENT IN SCI-MATH BY TOPIC, THE SEMESTER ELECTIVE SECTIONS

I. TOPIC COVERED BY EACH SCI-MATH TEST ITEM

In this chapter, the achievement on each item of the pre-test and its matched post-test will be analyzed. There were twelve questions on the pre-test which covered the separate topics in the elective semester sci-math course. These questions covered only those parts of the sci-math course which did not use special terminology; it was assumed that the control groups would not be able to answer questions with special terminology at all and that such questions were therefore unfair for comparison purposes. Table VII gives the numeration of the questions in the pre-test along with a description of each question; the post-test matched items were scrambled in order but are reported in the same numeration in this chapter.

The items may be grouped as follows:

Direct Proportions:

Calculation involving one proportion	1, 4, 7
Two or more proportions	2, 6
Measurement labels (also algebra)	3, 5
Algebraic application	8, 10
Graph	11

Inverse Proportions:

One proportion, word problem	9
Graph	12

Each question concerns a discrete type of problem and represents one of the levels in the perceived hierarchy of direct and inverse proportions.

Most of the schools in this study did not teach the latter half of the curriculum (items 3, 8, 9, 10, 11) as thoroughly as they did the first half (chapters one to four, items 1, 2, 4, 5, 6, 7). Sometimes, only one period was devoted to a chapter in the second half of the text; two schools covered only the first four chapters.

II. ANALYSIS OF PRE- TO POST-TEST GAIN PER ITEM

Table VIIIA presents an analysis of the mean gains on each question from pre- to post-test for each of the seven elective semester sci-math sections; Table VIIIB shows it for the pooled data. Significant gains are shown by asterisks, one for the 5% level, two for the 1% level, and three for the 0.1% level.

TABLE VII

TOPICS OF PRE-TEST ITEMS

Number	Descriptor	Sci-Math Chapter	Description
1	Percentage	4	Calculate the percentage of running figures in a drawing of stick figures.
2	Randomized 2-step proportion	2	Word problem. Two successive direct proportions. Data not given in order of calculations needed.
3	Denominate numbers* in an algebra equation	5	Given denominate numbers for y and in y = kx, what is x?
4	One-step proportion with distractor	2	Word problem with drawing illustrating the proportion.
5	Measurement labels in an algebraic equation	2	Given the measurement units for b and d in b = cd, give the units for c.
6	Orderly multi-step proportion	2	Five successive proportions; data given in order of use.
7	Ratio-rate conversion	3	Given a proportion arranged as an equality of two ratios, apply the fact that it can be rearranged into an equality of two rates.
8	Equation from data	5	Develop an algebraic equation for a one-step direct proportion given a table of integral data with three pairs of quantities.
9	Inverse proportion, one-step	6	Given the number of days and workers to do a job, calculate days for a different number of workers.
10	Factor of change, exponential	7	Given 2 algebraic linear and 2 exponential equations for two variables, state which show variables directly proportional to each other.
11	Graph, direct proportion	9	Given a series of curves on uncalibrated graphs, state which shows two variables which always change by the same factor.
12	Graph, inverse proportion	9	Given a series of curves on uncalibrated graphs, state which shows that yx = k.

*A denominate number, also called a quantity, is a measured number; it consists of a number and its measurement label, such as 0.2 lbs. or 5 people.

TABLE VIII

Comparison by T-Test of Gains from Pre- to Post-Test, By Item, Elective Semester, Experimental Sections Compared to Control

A. For the Individual Schools

Q	Zeta	Alpha	Beta	Delta	Gamma A	Gamma B	Epsilon
1	-0.046S	0.853S***	0.929S**	0.778S***	0.533S*	0.263S	0.309S
2	0.582S***	0.253S	0.800S***	0.330S	0.675S***	0.415S*	0.173S
3	0.529S	0.142	0.871S*	0.562S*	0.031S	0.186	-0.[illegible]
4	0.412S	0.547S*	0.500S	0.239S	0.408S*	0.520**	0.27[illegible]S
5	0.012S	0.100S	0.400S*	0.301S	0.675S***	0.415S**	0.167S*
6	0.483S**	0.700S***	0.900S***	0.693S***	0.824S***	0.508S**	0.503S**
7	0.183S	-0.037	0.057S	0.028S	0.075S	-0.111S	0.333S
8	0.065S	0.105	0.600S*	0.256S	-0.059S	-0.164	-0.030
9	0.353S	-0.253	0.500S*	0.119S	0.200S	0.263S	-0.109
10	0.00	-0.053	-0.143S	0.227S	0.055S	-0.254S	0.067
11	-0.158	-0.358	0.043	-0.307	0.443S*	0.492S*	0.200
TOTAL	2.415***	2.000*	5.457***	3.227***	3.859***	2.533**	1.682***
12	0.118	0.053	0.100	0.108	0.075S	0.152S	-0.030
STUDIED TOPIC	2.573***	1.868***	5.557***	3.534***	3.933***	2.142***	1.75[illegible]
APPENDIX C TABLE	57	63	69	75	81	87	99
N EXP	17	10	10	22	15	19	30
N CONTROL	19	19	7	16	17		33

TABLE VIII (continued)

B. Pooled Data

QUESTION	POOLED DATA	
	Comparison Between Exp and Pseudo-Control (Zeta & Alpha)	Comparison Between Exp and Real Control (Other 5 Sections)
1	0.315*	0.533***
2	0.508***	0.387***
3	0.181	0.274*
4	0.405***	0.376***
5	0.273**	0.298***
6	0.663***	0.633***
7	0.154	0.158
8	0.132	0.065
9	0.096	0.149
10	0.112	0.029
11	-0.166	0.170
TOTAL	2.672***	3.072***
12	0.108	0.608
APPENDIX C TABLE	37	37
N Exp.	123	123
N Control	38	73

Significant gains are shown at the 0.1% level for items 1, 2, 4, 5 and 6 for both pooled experimental compared to the pseudo control and to the real control groups. There was a significant gain at the 5% level on item 3 for the experimental versus real control group. These six items all concern the use of direct proportions.

Four items on direct proportions showed no significant gain. There are: item seven on converting a ratio proportion into a rate proportion, item eight on construction of an algebraic equation from data, item ten on recognition of whether variables in various types of algebraic equations are proportional to each other, and item 11 on graphical analysis. No significant gain was shown on items 9 and 12, both on inverse proportions. With the exception of the ratio-rate conversion, all of these topics appear in the second half of the curriculum. Some of these topics were not taught at all in some of the experimental classes, as mentioned earlier. In Table VIIIA, an S indicates that the topic was studied, even if only for one period.

Of the six items showing no significant gains for the pooled classes, it was observed that there was a significant gain in at least one of the schools for items, 8, 9, and 11. This suggests that a longer period of instruction for the second half of the course might have been helpful at the other schools. For the remaining three items, 7, 10 and 12, no significant gain was shown by any of the schools. Item 7 concerned recognition of the rates embedded in a ratio proportion; we have some doubts as to the validity of this question since some students gave answers that suggested interpretations other than what was expected. Item 10 involved recognition that exponential relationships and constant additive relationshps expressed algebraically are not direct proportions whereas equations of the type $y = kx$ shown proportionality of the two variables, a topic covered very briefly if at all by any of the classes. Item 12 was studied briefly by only one semester elective section.

The combined results for items 2, 4, and 6, three problems on direct use of single and multi-step proportions, were analyzed by a T-test. There was no significant difference between the scores of the pooled experimental group and each of the control groups (real and pseudo) on the pre-test; the scores were very significantly different on the post-test between the experimental group and each of the control groups. The gains from pre- to post-test likewise showed significant differences. See Table IX for the data.

The scores for the pooled experimental group for the four items involving algebra (3, 5, 8, and 10) were compared to those of the control group by a T-test. Again, whereas there was no significant difference in pre-test scores between experimental compared to real control and to pseudo control groups, there was a highly significant difference in each case for post-test scores, and for gain in pre- to post-test scores. See Table IX.

The significances obtained in the various schools on the separate and pooled items of the tests are shown in Table X. Overall, significant gains were achieved by at least one school for eight of the ten direct proportion items and one of the two inverse proportion items, and not obtained at all for two direct proportion items and one inverse proportion item.

III. SUMMARY

Students in the experimental group made strong gains in their ability to deal with applications of single and multiple-step proportion problems. The

TABLE IX

COMPARISONS BY T-TEST, ACHIEVEMENT ON GROUPED ITEMS IN SCI-MATH TEST

ITEMS	2, 4, 6			3, 5, 8, 10		
Keyword Descriptors	Single and Multi-step use of direct proportions			Algebraic applications of direct proportions		
	EXP	REAL CONTROL	PSEUDO-CONTROL	EXP	REAL CONTROL	PSEUDO-CONTROL
Pre-test Mean	0.407	0.521	0.553	0.650	0.562	0.684
Post-test Mean	2.008	0.726***	0.579***	1.480	0.726***	0.816**
Mean Gain	1.602	0.205***	0.026***	0.829	0.164***	0.132**

TABLE X

TEST ITEMS IN SCI-MATH: SUMMARY OF SIGNIFICANT GAINS IN ACHIEVEMENT[1]

Question	Keyword Descriptor	Significant for Experimental Group in Pooled Schools	Significant for experimental groups in at least one school in the pooled schools
1	Percentage	***	***
2	2-step, random data	***	***
3	Algebra, denominate	*	*
4	One-step	***	*
5	Labels, algebra	***	***
6	Multi-step, orderly	***	***
7	Rate in ratio proportion		
8	Write equation		*
9	Inverse proportion		*
10	Linear and exponential algebra		
11	Graph, direct proportion		*
12	Graph, inverse proportion		
2, 4, 6	Direct proportion, pure	***	
3, 5, 8, 10	Algebraic direct proportions	***	

[1]The asterisk shows significance as in Table II and here indicates the best significance obtained.

gains were less pronounced but still significa for algebraic and graphical interpretations of direct proportions. Gains for the inverse proportion were significant only at the two schools where it was studied while none made significant gains on graphical interpretations of inverse proportions including the one school where it was studied.

CHAPTER FOUR

FOLLOW-UP IN SCIENCE

I. INTRODUCTION

The original purpose of the sci-math project was to help students to apply the mathematics that they had already learned to the study of the sciences. After the project was started, the project staff realized that, first, new explanations and procedures in applied mathematics were required and, next, that the materials which were developed had wide applicability to consumer, commercial, and industrial calculations. In Chapter Two, it was shown that the sci-math curriculum is effective in teaching problem-solving for everyday applied proportional calculations. In this chapter, the effectiveness of the sci-math curriculum for aiding achievement in science will be examined.

To follow achievement in chemistry, one study collected data for those students in the experimental and control groups who took chemistry following their semester elective course in sci-math. Another study was conducted on achievement in chemistry when sci-math was selectively incorporated directly into the chemistry course; a corresponding study was conducted for achievement in physics.

II. THE CHEMISTRY TESTS

A. Teacher-made Chemistry Test

To measure achievement in chemistry, two tests were employed. The first test was a teacher-developed set of questions which was selected as follows. Each of the six schools participating in the semester elective sci-math field test was asked to submit the examinations for their regular chemistry course given in the previous year. These were culled by the Project Director who selected one representative teacher-made test question for each of the major topics of the course that required arithmetical calculations. Thirty items were submitted to Zeta to use in testing their pseudo-control group. Zeta administered all of the thirty items; after scoring, the Project Director eliminated or rewrote ten of the questions. The surviving 24 items were combined into the examination used for the follow-up in chemistry for the experimental and control sections for the semester elective course and for the chemistry experimental and control sections at Iota.

Each participating chemistry teacher was asked to use every question that covered a topic actually taught and to omit questions on topics not covered; each school used a different selection of test items. This was done because the curriculum differed from section to section depending upon the textbook used and the topics selected by the teacher. Hence, the results for the participating schools cannot be pooled, and will be separately analyzed.

B. Standardized Chemistry Test

It was clearly desirable to use a standardized chemistry examination in the field test. It should be noted that the use of a standardized test does not increase the acceptability of pooling the results. There is no standardized state-wide examination in the state of Connecticut; the chemistry teachers may teach whichever chemistry topics they wish to whatever depth they judge best. Hence, no two courses are the same, and the examination scores of different schools or even of different teachers cannot be compared or pooled in this study.

The only nationally standardized high school chemistry test available was the ACS-NSTA examination, an 80-minute two-part test of eighty items where either part of the test or the whole test may be used. The score on one part is expected to equal the score on the second part; the questions are different but the same topics are covered. The test includes all topics in the textbooks in common use; it is not expected that a "regular" course (*i.e.*, non-honors, college-bound students) covers all of the topics. All items have four choices. While approximately half of the items involve numbers, they also involve recall or concepts so that they are not simply based on problem-solving skills. The 1979 High School Chemistry Test was selected for the field-test; one-half (40 questions) was used. The mean raw score found nationally for "regular" classes taking both parts of this test was 38.8, $s = 15.1$. The norm for mean raw score for the honors students was 51.37, $s = 16.07$. Note that honors students were excluded from our sample population in this study, so that the norms that apply to our sample population are those for the regular group.

In retrospect, there are some serious doubts as to whether a 40-item multiple choice test with a mean score of 19½ was appropriate for comparisons of achievement for this population. By chance alone, a score of 10 can be achieved on this four-choice item examination. The norms obtained nationally show that up to 4% of the regular group correctly answer no more than 10 of the 40 questions compared to 3% of the honors group, whereas up to 54% of the regular group correctly answer only 19 questions or less compared to 24% of the honors group. Thus, almost 50% of the spread of the scores of the regular group takes place over 10 questions. Statistically, a difference in total score of about five to eight items (depending on sample size) is needed to show a significant effect on a 40-item test; this gain has to come out of the ten questions, an exceedingly high proportion. Because the test has many items on topics other than those involved in our study, such large gains cannot be expected. Hence, whether this test should have been used in this project must be questioned.

Epsilon used Part I of the ACS-NSTA test; Gamma and Delta each administered both parts.

III. CHEMISTRY RESULTS, ELECTIVE SCI-MATH SEMESTER GROUP

A. The Chemistry Sample

At every school which gave the elective semester of sci-math with the exception of Epsilon, the attrition rate between the semester of sci-math and the chemistry course the following year was high both for the experimental and for the control groups. Except for Epsilon, less than 50% of the student sample enrolled in chemistry the following year. Possibly, the recruitment effort for the one-time offering of sci-math attracted many students who were not planning to take chemistry until two years later or were not planning to take it at all. As a result of the high mortality rate in the sample, three schools, Alpha, Beta, and Zeta, had insufficient registration to permit a study of their outcomes in chemistry, so the progress of students in chemistry was followed only in Delta, Epsilon, and Gamma.

At Epsilon, three different teachers taught chemistry, at Delta, four, and at Gamma, two. At Gamma, the section taught by one of the teachers had only one student from the control group and eight from the experimental group; this teacher also administered a different ACS-NSTA examination. The decision was made to omit this teacher's group from the follow-up study because of these events.

Both control and experimental groups at Epsilon were all-male, juniors, with no significant difference in sci-math pre-test scores (see Table III).

The sci-math pre-test total mean scores for the nine chemistry students at Delta who were in the chemistry treatment group was 1.667 while it was 2.444 for the 9 students in the chemistry control group; the difference was not significant (34.8% level of confidence) by the T-test.

The sci-math pre-test scores for the 9 chemistry students at Gamma in the treatment group was 1.889 and for the control group was 3.375. The difference was close to significance (7.5%) by the T-test.

B. Achievement in Chemistry

The scores for the teacher-made chemistry tests and the ACS-NSTA examinations for those schools where students were followed-up in chemistry after their elective semester of sci-math are given in Table XI.

Two of the schools. Delta and Gamma, together totaling 17 experimental and 17 control students, showed no significant difference between the experimental and control groups in chemistry achievement. At Epsilon (24 experimental, 23 control students), teacher-made test scores were significantly higher for the

TABLE XI

COMPARISON BY T-TEST OF PERCENTAGE SCORES,
TEACHER-MADE AND ACS-NSTA CHEMISTRY EXAMINATIONS

		N	SCORES, TEACHER MADE TEST	SIGNIFICANCE T-TEST	ACS PART I	SIGNIFICANCE T-TEST	ACS PART II	SIGNIFICANCE T-TEST
ELECTIVE SEMESTER SCI-MATH	DELTA							
	Exp.	8	33	over 0.500	40	0.258	44	0.147
	Control	9	32		36		37	
	GAMMA							
	Exp.	9	71	over 0.500	55	over .500	57	over 0.500
	Control	8	69		57		58	
	EPSILON							
	Exp.	24	37	0.054	40	over 0.500		
	Control	23	24		41			
CHEM. AND SCI-MATH	IOTA A							
	Exp.	33	86	0.082			29	over 0.500
	Control	17	73				28	
	IOTA B							
	Exp.	19	77	0.001			27	0.321
	Control	14	51				24	

experimental versus control groups on the ACS-NSTA test.

IV. RESULTS, INTEGRATED CHEMISTRY- SCI-MATH COURSE

A. The Sample

At Iota, Teacher A taught two experimental chemistry sections and one control section, while Teacher B taught one chemistry experimental and one control section. The experimental A group had more males than females (7% level of significance). The B groups did not differ significantly in gender, and A and B experimental groups did not differ significantly from their control groups in highest mathematics studied or in grade level (see Chapter Two, Table II). The two A experimental sections did not differ significantly on the sci-math pre-test from the control group; the B experimental group scored significantly better on the pre-test than did the control group (see Chapter Two, Table IV).

It is not possible to pool the test data for chemistry achievement for the A and B groups as was done for the sci-math analysis because they took different teacher-made chemistry tests.

B. Achievement in Chemistry

The achievement of the 33 students in the A chemistry experimental sections differs from that of the 17 students in the A control group at a level which approaches but does not quite reach significance (8% level). The B groups showed a highly significant difference favoring the experimental group (19 experimental, 14 control students). There was no significant difference for either the A or B sections on the ACS-NSTA examination.

V. DISCUSSION AND SUMMARY OF CHEMISTRY FOLLOW-UP

The findings concerning the effect of sci-math study on chemistry achievement are not conclusive. Study of sci-math in an elective course made a significantly favorable difference in chemistry achievement the following year on a teacher-made test of problems involving calculations at one school. In two other schools where the total sample was less than that of the first school, no significant difference was shown. However, in one of those schools, the pre-test difference in sci-math in favor of the control group was so close to significance that these results shed little light on the question. Sci-math, it appears, can make a difference in some schools though, perhaps, not in all. Further study is certainly needed to replicate this experiment and seek the reasons for the variation.

No single experimental section did better than its control group on the ACS-NSTA test. However, the validity of the test for this study has been questioned.

When selected portions of sci-math was taught as part of a regular chemistry course, the analysis suggests that it may have indeed improved achievement in chemistry. However, in the case of the B section, the experimental group may have been superior achievers for other reasons since they scored significantly higher on the sci-math pre-test at the start of the experiment. For both the A and B experimental sections, the loss of six weeks of class time, approximately, out of the regular course time in chemistry which was instead devoted to sci-math not only did not lower the achievement of the experimental group compared to that of the control group but raised it, suggesting that the gain in understanding of mathematical problem-solving more than made up for the loss of time in chemistry instruction.

Changes in achievement in chemistry problem-solving are notoriously hard to obtain. Perhaps the greatest obstacle to the determination of whether a real improvement has occurred is the instructional practice of giving students sample problems to memorize. If the sample problems are sufficiently alike to test problems, the same procedure is used although not necessarily with any understanding. Test scores do not show whether the problem was solved by memorization or understanding.

When an experimental study such as this one, where broadly applicable techniques were taught, shows some cases where chemistry achievement was improved without giving intensive training, practice, or tutoring in sample chemistry problems, the results are unique. All other reported studies which showed gains in chemistry achievement involved training in specific chemistry problems rather than in non-chemistry, broadly applicable, mathematical problem-solving. Hence, this study suggests that sci-math is a tool of possibly significant potential for the improvement of chemistry achievement.

VI. ACHIEVEMENT IN PHYSICS

In Chapter Two, Section IV D, it was shown that the control group in the physics course was significantly superior to the experimental group in sci-math problem-solving both at the beginning and at the end of the physics course. Hence, the achievements in physics of these two groups are not directly comparable.

Table XII shows that the achievements in physics of the two groups (same as Table 128, Appendix B) did not differ significantly. Whether this was due to the sci-math instruction or due to the fact that other factors besides proportional problem-solving skills were involved in the scores cannot be ascertained.

TABLE XII

PHYSICS FIRST TERM AVERAGES, FINAL EXAM, AND SEMESTER AVERAGES

	Exp.	Real Control	Diff.	T-Test	Sig.
Physics First Term Average	n = 20 80.75	n = 18 80.17	0.583	0.212	over 0.500
Physics Final No. right	n = 17 18.41	n = 18 20.78	-2.366	-1.260	0.219
Physics Semester Average	n = 18 81.11	n = 18 84.50	-3.389	-1.220	0.233

CHAPTER FIVE

FORMATIVE EVALUATION

I. INTRODUCTION

The project used several different avenues to obtain data for a formative evaluation.

(1) An outside evaluator, Karen C. Cohen Associates, was employed by the project to conduct an independent formative evaluation of the field-test.

(2) The project administered written attitude tests to some of the student sample.

(3) A meeting of project teachers was held after completion of the elective semester of sci-math to evaluate and to make recommendations to improve the curriculum materials. Teachers also kept notes in a log during the semester which will be used to revise the materials.

A report on the information from each of these sources is given next.

II. OUTSIDE EVALUATION: DR. KAREN C. COHEN'S REPORT

Dr. Karen C. Cohen's report follows in its entirety.

FORMATIVE EVALUATION COMPONENT

OF THE SCI-MATH PROJECT -- SUMMARY REPORT

By

Karen C. Cohen, Ph.D.

July, 1981

INTRODUCTION

Providing formative evaluation feedback to developers and implementers of the Sci-Math Project during the past two years of the program was difficult for a variety of reasons. Perhaps the greatest difficulty involved adding any new information about the course to the course developer. This difficulty in finding new information was related to the virtually total mastery and control of the course and its implementation by Dr. Goodstein. Dr. Madeline Goodstein created the materials, nurtured the course through its early phases, and during the formal testing years (1979-1981) visited classes frequently, developed and provided additional materials on numerous occasions, and followed -- about as carefully as an individual can -- what happened to the implementation of her materials in several scattered sites.

A second difficulty confronting the "formative evaluator" related to the highly developed, intricate, and rigorous testing program and design which Drs. Goodstein and Boelke put into place around the implementation of the program and are carrying through. Not only did this testing program look at content, but it also looked at attitudes, skills, knowledge, career aspirations, and various related attributes which might again effect the implementation of the program. These data, gathered and analyzed exhaustively under the direction of Drs. Goodstein and Boelke, should provide a rich resource for a variety of studies relating to the project and relating to the general understanding of science on the part of students at this age as well.

Despite this careful scrutiny and measurement, however, we felt that there could be advantages to observing some classes and sending some questionnaires to students and teachers along with personal interviews. During the two years of the implementation and formative evaluation, i.e., 1979-80 and 1980-81, we attempted to put into place these kinds of traditional formative evaluation procedures. During the first year of implementation, we summarized and reported to the project what we had found, and a copy of those findings appears in the next section, Year I. During the second year of implementation, the originally-intended design fell apart to a certain extent with losses of students in experimental and control groups and also changes of schools involved. In Year II, therefore, we decided that an intensive analysis of the implementation of the course in one school involving a large number of classes and teachers would be of the most benefit. Section II, Year II, details our findings when we interviewed the teachers and students involved in that particular program.

YEAR I SUMMARY OF SCI-MATH COURSE

STUDENT EVALUATION*

Of the 126 students who took the course, the ratio of boys to girls was about 3:2.

Over 80% felt that the course was of some value in preparation for chemistry, and about 40% felt that it was above-average-to-excellent in value. The figures were quite similar for the value as a preparation for further math courses.

The amount of material which was new to the individual student varied widely. One out of four reported that less than 25% was new, and one out of two reported that over 50% was new.

The level of interest in the lecture portion was not very high, with slightly over 50% reporting "average," and over 90% reporting average or below. On the other hand, the lab exercises were regarded as of higher interest, with over 40% reporting "above average" to "excellent."

In general the students found the course to be of average difficulty or easy. The hardest topic was Proportion/Dimensional Analysis, which was singled out by 10% of the students.

By and large, the students found that the course made learning somewhat easier than usual, and took less time than usual to learn, but they were about evenly split on whether the course helped them learn more than usual compared to other science courses; they were also split on whether the course helped more than usual compared to other math courses.

*Detailed statistical descriptions of the populations and samples involved appear in the summative research report by Dr. Boelke.

About half of the students found some of the reading material confusing; only a few felt that it was too easy. and only a few felt that it was too complicated.

A high percentage thought that it should be given for one semester (as it was) rather than for a full year. Many thought it could be offered as a supplemental course for students with math difficulties. Very few thought it would be helpful as an advanced course for better students. (Both the boys and girls shared this sentiment.)

Half the students reported that Algebra should be taken before taking Sci-Math, and an additional significant number felt that both Algebra and Geometry should be studied first. There was a 3:2 ratio of students who thought that Sci-Math should be taken before taking Chemistry to those who thought it was unnecessary.

As expected, there was almost universal agreement among the pupils that the teacher for Sci-Math should have both a Math and Science background rather than either one alone.

The students rated the teacher well above average in ability

(a) to organize things properly,

(b) to give clear explanations,

(c) to make the class members think for themselves.

Also, they gave a high rating to the teacher's knowledge of the course material, and an above average rating to the teacher's ability to make the classes interesting.

None of the specific comments on what would make the course better recurred often. Those cited included (in decreasing order of frequency):

(a) making the course and the problems more interesting,

(b) more and better chemistry-related problems,

(c) rewriting the book to improve clarity,

(d) rewriting the book at a higher level,

(e) more practice problems and experiments,

(f) less repetitive material.

The girls felt a little more strongly than the boys that the course made learning easier than usual. In particular, most of the girls felt that it took less time to learn the material; the boys were evenly divided on this point. It was the sentiment of both the boys and girls that the course would be beneficial to students with math difficulties.

While most of the boys and girls agreed that the teacher had above-average ability to organize things well, a considerably higher proportion of boys rated the teacher "excellent" in this department. Similarly, a higher percentage of boys rated the teacher as excellent in ability to make the classes interesting. This type of sentiment was reflected in a similar vein by a relatively larger number of boys who felt that the teacher's knowledge of the course was excellent.

As might be expected, the students who planned to take chemistry next year showed a somewhat higher interest in the labs and lectures. Also, a larger proportion of those planning to take chemistry felt that the course made learning easier, and helped them learn more than usual with respect to other science courses. No such distinction was noted, however, about their ability to learn more than usual with regard to other math courses.

Again, as might be expected, a considerably larger percentage of students planning to take chemistry rated the teacher above average to excellent in knowledge of the course material, in ability to explain clearly, and in ability to make the classes interesting.

The expected value in preparing for Chemistry (but not Math) was rated considerably higher by those who planned to take chemistry next year than by those who did not.

YEAR I SUMMARY OF SCI-MATH COURSE

TEACHER EVALUATION

Of the seven teachers who completed evaluations of the Sci-Math Project, all but one recommended continuing to offer it; the one dissenter gave the reason that, in his case, another math course would have to be dropped, otherwise he would consider it. Three of the seven felt little or no modification was necessary. The others suggested some changes: in particular, blending or incorporating parts with other courses.

The teachers were unanimous in their estimation that the course met their objectives. One did find it beneficial to supplement with other material, to delete some problems, and to change the order of topics.

The teachers rated the students to be about average for their schools, about average compared to students throughout the United States. The teachers also mentioned that they considered their students to be below average in student level of interest. The amount of course material new to the students averaged about 75%. Six teachers felt that the course should be offered as a remedial course for students expected to have difficulty in chemistry. The course was regarded also as a good offering for an optional course for those interested, and good for one semester duration rather than two.

Most of the teachers rated the course material to be clear, organized, and about the right level of difficulty for the students.

Opinion was about equally divided on whether the teacher's manual was an integral part of the text material. Comments on changes or improvements to the teacher's manual included: adding more practice exercises and review problems; better synchronization of the manual with the student text; and reworking confusing sections. Each teacher suggested minor course changes, including:

(a) reduction of repetition and "cuteness,"

(b) integration with a math course,

(c) more science-related problems,

(d) insertion of experiments in physics and chemistry in a predetermined order, spaced through the course.

The teachers used about 13 of the labs on the average. The labs the individual teachers found least useful included:

(a) the ones requiring work outdoors, at a school where going outside during class is discouraged,

(b) Lab #17, which involved trig and geometry which the pupils had not yet covered,

(c) Lab #9 on counting a stack of pennies,

(d) Labs on finding page by measure, and figuring the weight of a car.

The labs found most useful by individual teachers comprised:

(a) Labs #10 and #11 which dealt with chemicals and chemical experiments,

(b) Lab #17, the trig experiment,

(c) Labs #16, 12, 14 which have immediate results to which students could relate, and which could be completed in one 40-minute period.

(d) Lab #2 on chemistry and heat.

The chapters found least useful by the teachers were Chapter 3 (reported confusing by two teachers), Chapter 4 (reported by two teachers), and Chapter 5 (reported by one teacher). Conversely, the chapters found most useful included

Chapter #	Cited by
2	5 teachers
1	4 teachers
5, 6	3 teachers
7, 8, 9	2 teachers
3, 4	1 teacher

Two teachers made no changes in the course while teaching it, and a third followed the book closely with minor variations (alternate methods of solution, additional worksheets for lab experiments). The others made alterations including

(a) change of teaching method,

(b) addition of slide rule and logs, answer estimation, simultaneous direct and inverse variation, worksheets on trig work,

(c) skipping some problems,

(d) changing some definitions,

The problems which the teachers had with the course included

(a) motivating students and keeping students' attention (in one case mainly because class met during the last school period),

(b) some of the labs were too lengthy,

(c) in one case, adapting to the fact that the majority of students were not there for the purpose of pre-chem preparation,

Six teachers felt that the teacher needs a math and science background, the seventh felt that either math or science was adequate. Five instructors agreed that students need a year of algebra before taking Sci-Math; two felt that geometry also was needed, and one felt that basic arithmetic was sufficient.

Additional teacher comments included these:

(a) A teacher's manual with sample data would be helpful for the lab phase.

(b) A course of this type is needed for many students as a transition from pure to applied math.

(c) The course is a refreshing approach to math, helpful in learning how to solve problems.

(d) There is enough material for about 3/4 of a year.

YEAR II SUMMARY OF SCI-MATH COURSE
STUDENT EVALUATION

In the school where we interviewed over 36 students at one high school covering a broad span of abilities, ages, and interests, and 6 teachers about implementation and carry-over of the Sci-Math curriculum, we also had the advantage of having an in tact control group, whom we also interviewed. In so doing, we discovered that the control group was "contaminated" by the materials presented in the other classes primarily because the teachers found that incorporating some of the activities and exercises developed in the Sci-Math materials would be helpful in their regular science teaching. The <u>biggest</u> complaint that we found -- and it is an important one -- was that students that had the Sci-Math course regretted not being able to cover as much of the material in the class in which it was placed as students who did not have to have Sci-Math. It was interesting that the students who were in the control group and not participating in Sci-Math still had quite definite opinions about Sci-Math. The course obviously commanded attention of everyone in science at the school. We interviewed seven control students, and we discovered that the majority held the following general opinions:

(a) Sci-Math is quite helpful in understanding problems and materials,

(b) Sci-Math is more challenging than other science courses,

(c) Sci-Math may be more work than many other science courses,

(d) the experiments in Sci-Math are a very interesting way to learn new material, and the experiments are very light,

(e) they dislike most the amount of time Sci-Math often took,

(f) they would change the course by reducing the amount of testing that it involves,

(g) they felt the course was very effective, and

(h) they felt that the Sci-Math explanations were sufficient.

The basis for these comparison group student opinions is obviously the work that they have done themselves with some materials assigned by the teacher and their conversations with other students. The general opinion, then, of the Sci-Math course even for those not participating in it is that it is interesting, helpful, teaches something worthwhile, and is probably not a waste of time although at times it is tedious and involves too much testing.

We asked similar questions of the students who actually were involved in Sci-Math -- in this instance additional interviews were done with students who were taking Sci-Math in conjunction with a variety of other science offerings. In the aggregate, their opinions were that:

(a) Sci-Math was a very good experience and they learned the material quite thoroughly,

(b) it was easier for many of them than other science courses and also has more new material than other science courses; a nearly equivalent number felt that it was more challenging than other science courses,

(c) the majority felt that Sci-Math was easier to understand than their other mathematics courses, and they were quite firm about that,

(d) a very large proportion felt that the experiments made Sci-Math far easier to understand, and a smaller number liked the change of pace that experiments allowed,

(e) most of them liked the fact that they did some "real learning" in the course and that the course was also "easy to understand,"

(f) they disliked most that it was sometimes boring repetitive,

(g) they would most frequently change the book or the text rather than other activities involved in the course, such as laboratories or experiments.

(h) In general, they felt that the course was extremely effective. Although few had additional comments, most frequent other comments were that Sci-Math should be used at a lower grade level than the tenth or eleventh grades (where these students were).

As the interviews continued and we explored in greater depth what they liked, did not like, and did with Sci-Math, the interviewer was most struck with the fact that a very large number of students reported using the Sci-Math concept, principles, and approaches in their everyday lives. Specific examples that were brought out involved buying automobile tires, cooking, and buying gasoline. Several students talked of new skills they could now apply and did apply in their everyday lives, emphasizing the utility of the concepts and skills in Sci-Math.

YEAR II SUMMARY OF SCI-MATH COURSE

TEACHER EVALUATION

When we interviewed the four teachers involved in teaching the several sections of Sci-Math in combination with either physics or chemistry as the case was in this school, we found that the ccurse was perhaps least satisfying for seniors in physics; it was seen as an "add-on" and by and large was seer as very easy. Even at lower grade levels it was seen as easy, and teachers felt that Sci-Math should be a part of a seventh-grade curriculum in beginning science rather than taught at higher levels. Some teachers felt it should be integrated with the general offerings, and other teachers felt that it should not be integrated but should be a course by itself. As they were considering and discussing the Sci-Math Project in a group interview, they reported that they had had to spend a good deal of time trying to integrate the materials into the courses that they were teaching. They did not really resent this personally, but they felt that they had perhaps taken away from some of the teaching that they should have been doing in their regular science areas. The group quite seriously was discussing the question as to how to fit these materials into a general curriculum and where to make a recommendation for its belonging best. There was no question or thought given to <u>not</u> using Sci-Math; rather, the interest was in how and when best to use it.

CONCLUSIONS

As a result of our teacher and student questionnaires and interviews over the past two years involving the Sci-Math curriculum, it is clear that the program is helpful, teaches new skills, is well developed and coherent and well received by students and teachers. Its biggest problem involves how and where to place it in traditional educational settings, the appropriate grade level, and its difficulty to implement since it involves a unit of time that does not mesh well with quarters, semesters, or year-long courses.

III. ATTITUDE TESTS

The Purdue Master Attitude Scale, Form A, toward any school subject was given to the students in the sample before the study of sci-math to assess their attitude toward mathematics and toward chemistry. Form B was used at the end of the instruction. The attitude forms used may be found in Appendix C. The attitude scale was graded according to its accompanying manual; on this scale, 1 represents the lowest attitude and 10.3 the highest attitude.

Table XIII (same as Table 10 in Appendix B) shows that there were significant differences prior to instruction in attitudes towards mathematics of the twelve experimental sections that were taught sci-math; scores range from 5.846 to 8.231. Likewise, there were significant differences in attitude toward mathematics of the seven sections out of the above twelve who took the semester elective course. However, T-tests of differences in attitude toward mathematics of the seven sections that studied sci-math as an elective course were not significant between any two of the schools; (see Table 17, Appendix B).

Table XIV (same as Table 11, Appendix B) shows the Spearman rank order correlation coefficient between the attitude towards mathematics of the experimental sections and the gain between the pre- and post-test. The correlation is positive, 0.37, but does not reach 5% significance.

Comparisons were made of the attitude toward chemistry prior to sci-math instruction of the sections taking the semester elective sci-math course: see Table XV (same as Table 18, Appendix B). The scores ranged from 3.964 to 6.615. Except for Epsilon compared to Gamma A, there were no significant differences in attitude toward chemistry between any two of the seven sections. A Spearman rank order correlation coefficient between gain in sci-math pre- to post-test scores and attitude toward chemistry showed no significant correlation; see Table XVI (same as Table 20, Appendix B).

At Epsilon, the experimental and control groups for the semester elective sci-math course were post-tested as well as pre-tested for attitudes towards mathematics and chemistry. The data is reported in Table XVII (same as Table 101, Appendix B). There were no significant differences between the control and experimental groups in attitudes toward chemistry and toward mathematics on either the pre-test or the post-test.

At Iota, the pre- and post-test attitudes of the students in the treatment and control section s were tested; see Table XVIII (same as Table 152, Appendix B). There was no difference between attitudes towards chemistry between the two groups either on the pre-test or on the post-test. In attitude toward mathematics, the pre-test attitude scores did not differ significantly; however, the post-test score of the experimental group decreased while those of the control group increased. Consequently, there was a significant difference at the 99.9% level of confidence between the post-test scores on attitude toward mathematics. We shall not attempt to interpret this.

TABLE XIII

COMPARISON OF ATTITUDE TOWARDS MATHEMATICS BETWEEN THE SCI-MATH CLASS SECTIONS BEFORE STUDYING THE CURRICULUM MATERIALS

CLASS	MEAN	N	MEAN SQUARE	F-TEST	SIG.
Zeta	5.846	13	Among 9.5067	2.927**	0.002
Eta, Phy. Science	5.996	14	Within 3.2475		
Iota Chemistry Teacher A	6.673	36			
Alpha	7.257	7			
Iota Physics	7.355	20			
Epsilon	7.620	29			
Delta	7.715	20			
Theta	7.723	17			
Iota Chemistry Teacher B	7.792	20			
Gamma Teacher A	7.803	15			
Beta 1	8.200	9			
Gamma Teacher B	8.231	16			

IV. TEACHER RECOMMENDATIONS

A. Report on Meeting on Evaluation of Semester Elective Sci-Math Course

Upon completion of the semester of sci-math instruction as a separate course, the teachers met to make recommendations and suggestions. Following is the report of that meeting which was then circulated to the teachers. See Appendix A for a copy of the evaluation report.

B. Teacher Ratings of Laboratory Experiments

The participating teachers in the study kept a log of comments on the text and experiments. These comments will be used in revising the course for publication. In addition, the teachers rated each experiment upon a rating from; the results are shown on Table XIX.

C. Supervisor Evaluation, Sci-Math as a Part of the Regular Chemistry and Physics Course at Iota

The following is the supervisor's report.

> The Sci-Math curriculum at Iota was taught as an integral part of a one-year chemistry course and a one-year physics course. The teachers participating in the project included... the chemistry teachers involved a total of fifty-four students in their three experimental groups and a total of thirty-one students in their control groups. Eighteen physics students formed the control group and eighteen more, the experiment group.
>
> As the Sci-Math curriculum was integrated into the existing courses, it became apparent that a considerable amount of instructional time would be required to complete the mastery of the material. Consequently, the experimental groups in both chemistry and physics were found to be approximately one unit of work in arrears of the control group.
>
> All participating teachers were in agreement that there was perceptible improvement in the experimental groups in the mastery of such topics as nature of variables, dimensional analysis, rates and equations, and inverse proportions. Portions of the Sci-Math curriculum will be compressed and modified by these teachers to be incorporated into chemistry and physics courses at Iota beginning in fall, 1981.

TABLE XIV

RANK ORDER CORRELATION COEFFICIENT BETWEEN
ATTITUDE TOWARD MATHEMATICS AND GAIN IN SCI-MATH SCORE

	Att. Math	Gain	Diff in Rank	d^2
ZETA	1	8	-7	49
ETA	2	7	-5	25
IOTA CHEMISTRY A	3	4	-1	1
ALPHA	4	6	-2	4
IOTA PHYSICS	5	2	3	9
EPSILON	6	1	5	25
DELTA	7	10	-3	9
THETA	8	5	3	9
IOTA CHEMISTRY B	9	3	6	36
GAMMA TEACHER A	10	12	-2	4
BETA	11	11	0	0
GAMMA TEACHER B	12	9	3	9
$r_s = 1 - \frac{6\Sigma d^2}{N^3-N} = 0.3706$ Not Significant $\Sigma d^2 = 180$				

The critical value at 5% for N = 12 is 0.506

TABLE XV

COMPARISON OF ATTITUDE TOWARDS CHEMISTRY BETWEEN THE ELECTIVE SCI-MATH CLASS SECTIONS BEFORE STUDYING THE CURRICULUM MATERIALS

CLASS	GAMMA TEACHER A	ZETA	ALPHA	DELTA	GAMMA TEACHER B	EPSILON	BETA
MEAN	3.964	4.985	5.043	5.155	5.396	6.439	6.615
N	14	13	7	19	15	28	10
Mean Square Among	12.9078	Mean Square Within	4.0352	F-Test	3.199**	Sig.	.007

TABLE XVI

SPEARMAN RANK ORDER CORRELATION COEFFICIENT BETWEEN GAIN IN POST-TEST OVER PRE-TEST AND ATTITUDE TOWARD CHEMISTRY, ELECTIVE SCI-MATH SECTIONS

	RANK OF GAIN	RANK OF ATT. TO CHEM.	DIFF IN RANK	d^2
EPSILON	1	6	-5	25
ALPHA	2	3	-1	1
ZETA	3	2	1	1
GAMMA TEACHER B	4	5	-1	1
DELTA	5	4	1	1
BETA	6	7	-1	1
GAMMA TEACHER A	7	1	6	36
$n = 7$ $r_s = 1 - \frac{6\Sigma d^2}{N^3 - N} = 0.178$				$\Sigma d^2 = 66$

The critical value at 5% for N = 7 is 0.714.

TABLE XVII

ATTITUDE TOWARDS CHEMISTRY AND MATHEMATICS, EPSILON

SUBJECT	EXP. MEAN	CONTROL MEAN	DIFF.	T-TEST	SIG.
CHEM. PRE-TEST	n=28 6.43	n=30 5.84	0.59	1.200	over 0.500
POST-TEST	n=18 6.19	n=16 6.66	-0.47	-0.808	over 0.500
GAIN	n=16 -0.14	n=14 1.32	-1.42	-0.247	over 0.500
MATH PRE-TEST	n=29 7.62	n=32 7.67	-0.05	-0.130	over 0.500
POST-TEST	n=22 6.34	n=23 5.88	0.75	1.205	over 0.500
GAIN	n=21 -1.86	n=22 -1.96	-0.18	-0.247	over 0.500

TABLE XVIII

ATTITUDE TOWARDS CHEMISTRY AND MATHEMATICS
IOTA, TEACHER A AND TEACH B COMBINED

SUBJECT	EXP. MEAN	CONTROL MEAN	DIFF.	T-TEST	SIG.
CHEM.	n=56	n=56			
PRE-TEST	6.59	6.59	0.00	0.012	over 0.50
	n=51	n=31			
POST-TEST	6.54	6.53	1.51	0.037	over 0.50
	n=49	n=26			
GAIN	-0.22	-0.11	-0.10	0.0205	over 0.50
MATH	n=56	n=32			
PRE-TEST	7.07	6.91	0.47	0.391	over 0.50
	n=51	n=30			
POST-TEST	6.21	7.75	0.27	-3.455***	under 0.001
	n=49	n=26			
GAIN	-0.98	0.97	-0.42	-4.143***	under 0.001

TABLE XIX

EXPERIMENT RATINGS

Rating Scale: 5 SUPER
4 GOOD
3 SO-SO
2 POOR
1 DISLIKE IT

NAME OF SCHOOL

Experiment	Title	Page	Alpha (Chem)	Gamma (Math-Chem)	Eta (Chem	Zeta (Chem.)	Beta (Math)	Epsilon (Math-Chem)	Delta (Math)	AVG.
1	.... Making Your Own Calibrated Test Tube	1	4	1	4	4		3		3
2	.... The Pennies Experiment	7	4		4	5	4	4		4
3	.... Human Measurements	9	3	4	5	3	5	4	4	4
4	.... How to See Through a Sealed Paper Bag	17			4					4
5	.... Which Would Be Easier to Pick Up?	21			4					4
6	.... How Thick Is a Page?	22		1	3	4	4	3	4	3
7	.... How Many Blades of Grass Are On a Football Field?	24	5		3		3	3		3½
8	.... Weighing a Car Without a Scale	25			5			3		4
9	.... How to Count a Stack of Pennies	29			3	4	3		4	3½
10	.... The Invisible Solid	30			5					5
11	.... Comparing Brands of Vinegar	35	5		5					5
12	.... A Natural Ratio: The Circle	39		5	4	4	4	3	4	4
13	.... Enlargement: 1. Rubberband Enlarger	43			3					3
14	.... Enlargement: 2. The Overhead Projector	48				5	4	3		4
15	.... Enlargement: 3. Enlarging a Map	49				5				5
16	.... Army Cooking	51					5			5
17	.... A Universal Ratio: Sides of a Given Angle	54		4		3	3	3	4	3½
18	.... How High Is the School? The Flagpole? A Rocket?	58						4		
19	.... How Does the Pendulum Clock Work?	60						4		4
20	.... Spaghetti Science	62				4	4			4
21	.... What is the Constant Relationship?	64			4				3	3½
22	.... Humble Tool; Big Principle	66						3		3
23	.... Bicycle Pedaling	70						3	3	3
24	.... The Turn of the Screw	74				5		4	4	4
25	.... A Law of Nature	79				4	4			4
26	.... Heat and More Heat	85								
27	.... Volume of One Penny	89		5					4	4½
28	.... Chemical Heat	94								
29	.... Pages and Pages	98		4					4	4
30	.... Stress Test	101		3					4	3½
		TOTAL EXPS.	5	9	13	12	11	14	11	

*Teacher's Certification is Given in Parentheses.

CHAPTER SIX

DISSEMINATION

I. INTRODUCTION

Dissemination of the work of this project was carried out in four modes:

1. Presentation of papers and workshops at meetings of mathematics and science education associations.
2. Publications in mathematics and science journals.
3. Newsletters mailed to teachers.
4. Process of seeking a commercial publisher.

Each of these will be reported on next.

II. PRESENTATIONS

A. Papers

The following papers were presented by Madeline P. Goodstein, Project Director.

June 27, 1978 "Preliminary Course in Mathematics for Introductory Chemistry," American Chemical Society, 8th Northeast Regional Meeting, Boston, Massachusetts.

August 24, 1978 "Mathematics for Introductory Science, "Forty-first Annual Summer Conference, New England Association of Chemistry Teachers, Wheaton College, Norton, Massachusetts.

November 18, 1978 "Mathematics for Science," Connecticut Science Teachers Association Autumn Conference, Trinity College, Hartford, Connecticut.

March 9, 1979... and William W. Boelke, "Rates vs. Ratios or Is a Marriage of Science and Math Teaching Possible?" Assoc. of Teachers of Mathematics in Connecticut, Spring Meeting, Meriden, Conn.

March 31, 1979 "Dimensional Analysis: Use of Misuse?" Chemical Colloquium, American Chemical Society, Connecticut Valley Section, Springfield, Massachusetts.

October 26, 1979 "A New Course in Mathematics for Secondary Science," National Science Teachers Association Area Convention, Hartford, CT.

November 2, 1979... with W. W. Boelke, "Rates vs. Ratios, or Can We Bridge the Gulf between Science and Math Teaching?" Assoc. of Teachers of Mathematics in New England, Annual Fall Conference, Springfield, Massachusetts.

March 18, 1980 "Math/Science Curriculum," New Britain High School Teachers meeting, New Britain, Connecticut.

March 23, 1981 "A New Secondary Course in Mathematics for Science," National Science Teachers Association, 28th National Convention, Anaheim, California.

April 12, 1980... and W. W. Boelke, "A Pre-Chemistry Secondary Course on Proportional Calculations," National Association for Research in Science Teaching, Annual Meeting, Boston, MA.

May 10, 1980 "A Course in The Everyday Mathematics Needed for Science," National Science Foundation Project Director's Meeting, Washington, D.C.

June 26, 1980 "Math for Introductory Chemistry in a Black Hole," Division of Chemical Education, American Chemical Society, 6th Biennial Conference, Rochester, New York.

November 8, 1980 ...with W. W. Boelke, "Teaching Rates in Preparation for Chemistry," Association of Teachers of Mathematics in New England, Providence, Rhode Island.

B. Poster Sessions

The following poster sessions on sci-math were conducted by Madeline P. Goodstein.

August 14, 1980, 42nd Annual Summer Conference, New England Association of Chemistry Teachers, New London, Connecticut.

February 5-7, 1981 National Science Foundation Director's Meeting, Washington D.C.

April 4-5, 1981 National Science Teachers Association, National Conference, New York, New York.

August 14, 1981 43rd Annual Summer Conference, New England Association of Chemistry Teachers, North Adams, MA.

C. Workshops

November 5-6, 1981 "Alternatives for Slow Learners," Arden House, Harriman, New York, two workshops in mathematics.

III. PUBLICATIONS

The following publications by Madeline P. Goodstein on sci-math are noted:

"Caught Between the Horns," Connecticut J. Science Education, 16 (1), 1 and 15 (1979).

"Evaluation of a New Curriculum," Connecticut J. Science Education, 16 (2), 45-6 (1979).

...with W.W. Boelke, "A Pre-Chemistry Course on Proportional Calculations, "ERIC, ED 184 896, April, 1980, 12 pp.

...with W.W. Boelke, "Sci-Math Project," The Mathematics Teacher 14 (6) 477, 1981.

In addition, a paragraph describing the project and inviting teachers to submit their names for the mailing list of our newsletter appeared in over twenty state science teachers and state mathematics teachers newsletters, in "The Science Teacher", and in "Children and Science."

IV. NEWSLETTERS

Five newsletters were mailed to teachers upon request. By the fifth newsletter, the mailing list was composed of over 600 teachers of chemistry and mathematics. See Appendix D for copies of the newsletters.

V. BOOK PUBLICATION

As per the approved Plan of Publication submitted to the National Science Foundation, a letter (see next page) soliciting publication was sent to over forty commercial publishers active in secondary science and mathematics. Also, advertisements were placed in the Educational Marketer and Publishers Weekly. Requests to see the materials were received from Teachers College Press, Silver Burdett, Random House, Macmillan, Holt Rinehart and Winston, and Ginn & Company publishing houses. Of these, all except Teachers College Press had responded to the letter of solicitation; Teachers College Press responded to the advertisement in Publishers Weekly. All eventually replied negatively except for Teachers College Press; all praised the materials but felt that the contents were too innovative for their programs and/or there was no room for it in the secondary curriculum. Copies of the advertisements and letter of solicitation appear at the end of this section.

Just before closing the contract with Teachers College Press, Dr. Bell of the Advisory Committee arranged for the Addison-Wesley Publishing Company, Inc., Innovative Division to review the text. They made an offer for publication. Because Addison-Wesley has an active sales force which attends meetings and conferences and visits schools shereas Teachers College Press relies solely on mail releases, the contract went to Addison-Wesley Publishers with National Science Foundation approval.

STATE OF CONNECTICUT

BOARD OF HIGHER EDUCATION

CENTRAL CONNECTICUT STATE COLLEGE

August 26, 1980

Dear Publisher:

The Sci-Math Project has developed a textbook and laboratory manual for a course in secondary mathematics for applications to science. The Sci-Math Project is funded by the National Science Foundation and has its headquarters at Central Connecticut State College in New Britain.

The textbook has been developed and extensively tested to teach proportional calculations using everyday, familiar variables rather than those from science. It includes direct and inverse proportions, dimensional analysis, percentages, connection between ratios, rates, and proportions, analysis of an equation, setting up simple equations from data, and graphing. The laboratory manual contains simple experiments with familiar inexpensive materials such as spoons, egg beaters, rulers, rubberbands, and C-clamps.

The textbook and manual may be used for a one-semester course or may be be separated into modules to be selectively used for eighth to eleventh grades. The course may be taught by mathematics teachers or by science teachers.

Science teachers have long complained about the inadequate preparation of their students and the new emphasis on basics has finally brought this to the attention of mathematics teachers. Since February, we have received over six hundred requests from teachers all over the nation for more information about our course, and about one of every six letters has included a personal note telling how much such a course is needed.

Central Connecticut State College is prepared to grant permission for the publication of these materials.

Publishers are invited to submit proposals by October 1, 1980. Please contact Dr. M. Goodstein, Department of Chemistry, Central Connecticut State College, New Britain, CT 06050, for examples of the text and laboratory manual.

Yours truly,

Madeline P. Goodstein, Professor
Director, Sci-Math Project

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